PIER Demand Response Research Center Plan

Developed by Lawrence Berkeley National Laboratory
and the California Energy Commission

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1 INTRODUCTION 3
1.1 Background... 3
1.2 Research Center Objectives 3
2 ORGANIZATIONAL STRUCTURE 4
2.1 Institutional Structure 4
2.2 Management Structure 4
2.3 Research Planning Process 6
2.4 Stakeholders and Market Connections 7
3 RESEARCH SCOPE 8
3.1 Policies, Programs, and Tariffs 8
3.2 Utility Markets, Technology, and Systems 9
3.3 Customer and End-use Technology and Systems 11
3.4 Consumer and Institutional Behavior 12
4 NEXT STEPS 13
APPENDIX - INFORMATION MANAGEMENT FOR DEMAND RESPONSE 14

1 Introduction

This document was developed to facilitate the planning process for a Public Interest Energy Research (PIER) Demand Response Research Center (or "Center"). It is intended to act as a framework to define (1) the institutional and organizational structure of the Center, and (2) the initial scope of the research to be conducted at the Center.

The document covers the following topics. The next two subsections (1.1 and 1.2) review background definitions of Demand Response (DR), policy objectives, and the objectives of the Center. Section 2 describes the proposed organizational structure of the Center. Section 3 provides an outline of the demand response (DR) research and development (R&D) topics expected to define the scope of the Center. This outline provides a starting point for discussions regarding the organization and prioritization of research at the Center and will be refined as discussions progress. Section 4 outlines a series of proposed steps to launch the Center. The Appendix describes research that is being considered as a core project for the Center's initial research activities.

1.1 Background

For the purposes of this report, Demand Response (DR) is defined as: *(1) load response managed by others for reliability purposes, (2) load response managed by others for procurement cost minimization purposes (e.g., load bidding), and (3) price response managed by end-use customers for bill management.*[1] Load response is typically attained through interruptible tariffs and direct load control programs. Price response can be attained through time-of-use rates, dynamic pricing, and demand bidding programs.

The two main drivers for widespread demand responsiveness are the prevention of future electricity crises and the reduction of average electricity prices. Additional goals for price responsiveness include equity, through cost of service pricing, and customer control of electricity usage and bills.

Demand response has been identified as an important element of the State of California's Energy Action Plan, which was developed by the California Energy Commission (CEC), California Public Utilities Commission (CPUC), and Consumer Power and Conservation Financing Authority (CPA). The CEC's 2003 Integrated Energy Policy Report also advocates DR (Docket No. 02-IEP-1).

1.2 Research Center Objectives

The main objective of the Center is to *develop, prioritize, conduct, and disseminate research that develops broad knowledge with the aim of facilitating the near-term adoption of DR technologies, policies, programs, strategies and practices, while ensuring that the research continues to be connected with the DR market and policy makers*

[1] The CA ISO refers to these two concepts respectively as "dispatched load" and "demand elasticity."

through substantial stakeholder input. Key stakeholders in the Center include system developers, aggregators, program implementers, utilities, industry trade associations, state policy makers, researchers, building owners, engineers, and operators, building equipment manufacturers, other end-use customers.

In attaining this objective, the Center will focus on the following activities:

- Create a PIER Research roadmap for DR in California to identify the R&D needed to solve practical and technical DR issues
- Establish multi-institutional partnerships to broaden the expertise of Center researchers and leverage funding
- Foster connections with stakeholders through outreach efforts
- Sustain long-term attention to DR research topics
- Conduct DR related research, development, demonstrations, and technology transfer

2 Organizational Structure

As a guiding principle, Center activities will be multi-institutional in concept and operation. LBNL will host the Center; guide Center development and provide technical, operational and planning leadership. The new Center director will actively solicit stakeholder input and adopt the research topics accordingly. The Center director will also seek the most qualified performers for projects. It is anticipated that researchers outside of LBNL will do a significant portion of research.

2.1 Institutional Structure

The Demand Response Research Center will be a multi-institutional organization in several ways. The Partners Planning Committee, Technical Staff, Research Performers and Project Advisory Committees will include people from multiple institutions collaborating within the Center. The roles and responsibilities of these groups are provided below.

2.2 Management Structure

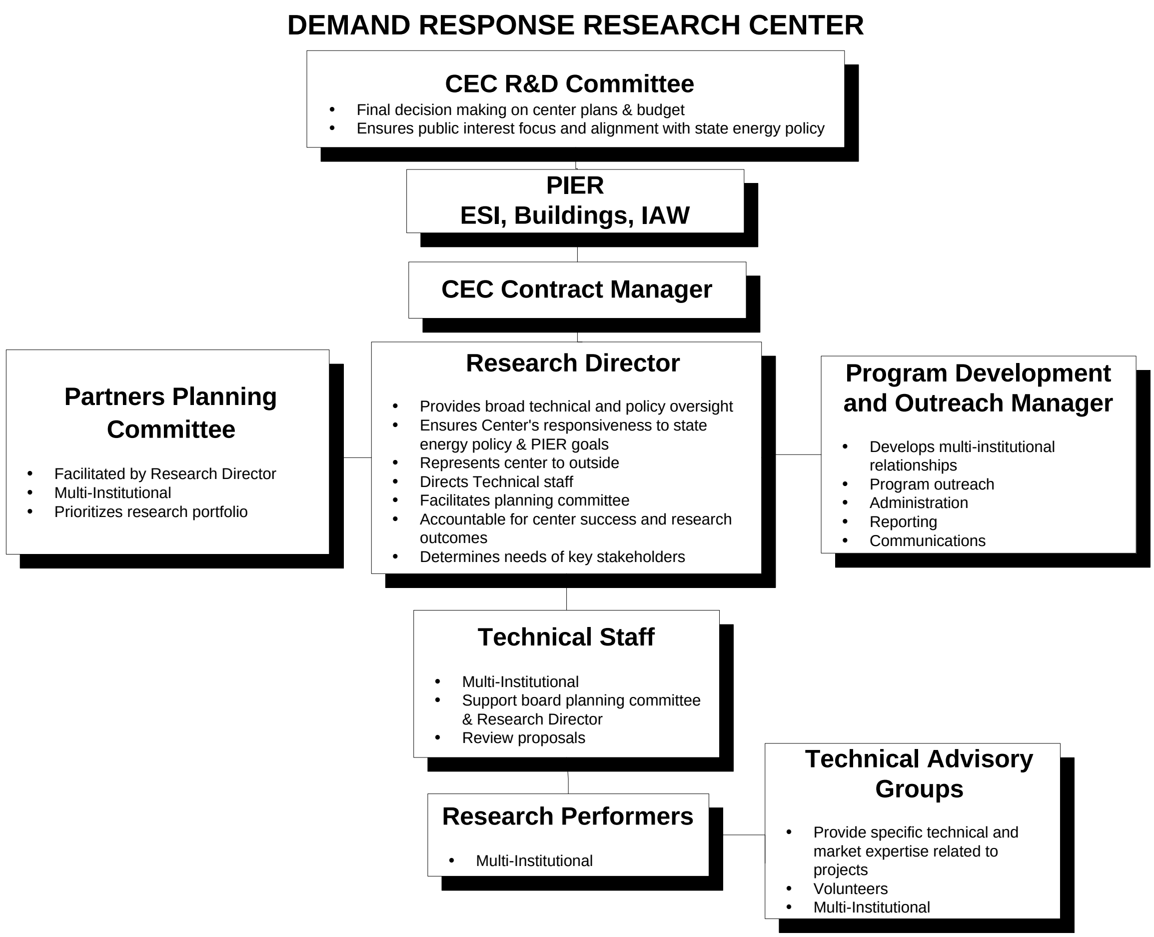
The proposed structure of the Center is shown in **Figure 1.** This structure is subject to change if it is found to be ineffective in obtaining involvement from stakeholders in research planning.

The **CEC Contract Manager** will be identified to provide CEC oversight. The CEC Project Manager will work with the Program Managers from the Buildings Program, Energy Systems Integration, and the Industrial Program.

The **Research Director** will manage the Center, providing broad technical and policy oversight and accountability for the Center’s success and research outcomes.

Responsibilities include ensuring that the Center is responsive to state energy policies and PIER goals and representing the Center to outside entities. Additional responsibilities include managing planning committee meetings, and determining the R&D needs of key stakeholders (see Section 5). The Research Director will form and direct Technical Staff, whose responsibilities are described below. The Research Director will report to the CEC Project Manager, and obtain guidance for Research and Development prioritization from the Partners Planning Committee. The Research Director will also manage a Program Development and Outreach Manager whose responsibilities are described below.

Figure 1. Demand Response Research Center Organizational Chart



The **Partners Planning Committee** will be a multi-institutional group to provide high-level guidance on R&D opportunities, priorities, and budgets. The Research Director will facilitate the Committee meetings and correspondence. California state public agencies such as the Public Utilities Commission (CPUC), the Independent System Operator (ISO), and the Power Authority will have a seat on the Committee. For-profit agencies (such as Utilities) and non-California public agencies (such as the U.S. DOE), will require $50k annual fee for membership on the Committee.

The **Program Development and Outreach Manager**, under the direction of the Research Director, assists in running the DR Center. Responsibilities include assisting in multi-institutional program outreach and partnerships, administration of Center activities such as budgets, staffing, and reporting. The Program Development and Outreach Manager will also be responsible for external communications, electronic and printed media, web site development, meeting and conference planning, and other outreach functions.

The **Technical Staff** will be recruited from multiple institutions. This staff will have expert knowledge in specific DR areas such as technology, markets, or policy. The Technical Staff provide expert briefings to the Partners Planning Committee on DR topics under the direction of the Research Director. They also help develop project plans, develop review criteria to assess projects, review proposals, provide comments on research products, and assist in linking the Center to key stakeholders. The Technical Staff will contribute to the Center research oversight and project management.

The **Research Performers** conduct research. The Center will fund research at multiple institutions, and multi-institutional research teams are encouraged.

The **Technical Advisory Groups (TAGs)** provide guidance to the Research Performers on technical and market issues of Center projects. The PAC will be a multi-institutional group of volunteers with strong interests in the project subject matter.

2.3 Research Planning Process

The Center will create research planning, project selection and project evaluation processes to develop an initial set of research projects, a multi-year research plan, and project management methods. The planning process will begin with a review of current DR research, after which the Research Director and Technical Staff and will propose an initial set of projects. These projects will then be adjusted to reflect feedback from the Partners Planning Committee organized through an annual research-planning meeting.

To ensure that the R&D planning is well balanced and relevant, planning should begin with an evaluation based on the following information:

- What State policies does Center research intend to address?
- What is the range of DR research topics considered?
- How should research be prioritized?
- Who should provide technical guidance and how should this group function?

Research at the Center will follow PIER policy by addressing key questions before beginning each project. First, does the project advance science and technology? Second, does the project provide public benefits not adequately addressed by competitive or regulated markets?

The research planning process will maintain the flexibility to adapt to changes from outside research methods and results. The Center will consider a research planning process that combines scenario analysis with an assessment of current DR Research and

Development and gap analysis. The Center will complement, reinforce and leverage current Energy Systems Integration, Buildings, and Industrial Program research and avoid overlap.

The research agenda for the Center will be carefully coordinated with the evaluations of DR programs and tariffs in California, throughout the nation and beyond, many of which are experimental in nature. Results of these experiments are expected to provide critical information on the feasibility and effectiveness of various DR programs, tariffs, technologies, and information systems. In particular, the Center will closely track the work and results of the three Demand Response Working Groups established under CPUC Rulemaking 02-06-001.

2.4 Stakeholders and Market Connections

A major element of the Center will be the strong market connection developed for each and every project. A concerted effort will be made to involve a variety of stakeholders in Center planning and on the actual research teams. Members of the Partners Planning Committee are likely to be representatives of the most direct stakeholders of the Center, including:

- Control, Metering and Information System Developers
- Aggregators and Program Implementers (could be subset of previous group)
- Utilities
- Policy Makers

Technical Staff will also be chosen from these stakeholders, as well as from other important stakeholder groups, including:

- Industry Trade Associations
- Researchers
- Building Owners, Engineers, and Operators
- Building Equipment Manufacturers

The decision regarding who and how these other research organizations are recruited will be developed as the Research Director and the Partners Planning Committee are developed. In some cases the Center may recommend the formation of multi-institutional research teams for topics with multiple interested parties.

In addition to the broad-based involvement of stakeholders as described above, market connection strategies will include:

- An extensive web site with project descriptions, resources, publications, and other related outreach material (both research and educational material will be included, along with links to other key material available at other sites)
- An Internet-based newsletter, professionally developed and disseminated to a broad group of stakeholders
- Research reviews and evaluation summaries to characterize lessons learned from past research and follow-on key questions regarding future research
- Project brochures and papers summarizing research results for multiple audiences

- Educational material for utility, building associations, and related organizations
- An annual DR research conference for public dissemination of general research results
- Semi-annual project briefings for key stakeholders to disseminate targeted research results.

3 Research Scope

Demand Response is a multifaceted issue with technical, policy, economic, and behavioral aspects. The Center's research agenda is intended to be crosscutting, practical, and relevant, with a goal of fostering an understanding of the intersection of the complex factors that influence "what works." This will require examining specific technologies, end-use control strategies, behavior, markets, DR program designs and the interactions of all of these factors. The draft framework for the Center research agenda provided here proposes four major DR research categories.

- Policies, Programs, and Tariffs
- Utility Markets, Technology, and Systems
- Customer and End-use Technology and Systems
- Consumer and Institutional Behavior

Below is a brief description of research issues and topics in these four main research areas. This broad outline of research topics is provided to define a starting point for discussions regarding the organization and prioritization of research at the Center. The outline will be refined as discussions progress.

3.1 Policies, Programs, and Tariffs

The research agenda for the Center needs to be carefully coordinated with State policy and policy research. The Center will closely track the results of the State investigation of DR issues under CPUC Rulemaking 02-06-001, which is evaluating the effectiveness of critical peak pricing tariffs during the summers of 2003 and 2004. Following are example research questions for discussion purposes.

Programs and Tariffs

Demand response efforts are generally categorized as either emergency based load response or price response such as dynamic tariffs. There are critical differences between such programs and tariffs. Recent program evaluations are beginning to report on the effectiveness of load response programs, but empirical information about DR tariffs and price response is limited. Results from the State investigation of DR are expected to shine light on price elasticities and customer response issues.

Additional research is needed in these areas. One issue the Center is likely to study is how dynamic tariffs and DR programs interact with long-term efficiency, conservation, and load shifting behavior.

Measurement and Evaluation Techniques

One critical aspect of DR that is not well understood is how to measure and evaluate DR. For example, while one objective of DR is to lower market prices, better methods are needed to evaluate the mechanisms by which DR affects overall market prices. A second example is the need to understand how to "measure" DR as a dispatchable resource for use by the ISO. What measurement and sampling techniques are needed to characterize the DR resource so it is more equivalent to dispatch of supply-side resources in the ISO control room? What are the costs to implement such measurement systems? What other benefits might such measurement systems offer?

Societal Issues

Perhaps the most neglected question in past DR research is: What unintended (positive or negative) societal effects are possible from widespread DR programs and tariffs? Some limited research has been conducted on the effects of DR on air pollution. Other possible effects to be studied include effects on energy awareness, working hours and income transfer.

3.2 Utility Markets, Technology, and Systems

The Center will track research related to DR issues at the utility and grid system level and incorporate relevant issues into the research agenda. For example, a recent CEC report describes interviews with key staff at the California Independent System Operator and resulting research priorities.[2] Some of these priorities are reflected in the topics discussed below.

Impacts of Demand Response on Grid Reliability

Supply has historically been used to rectify supply-demand imbalances. There is need to investigate strategies that allow DR to become as reliable as generation, thus utility and grid system operators could exploit load as a resource without hesitation. For example, system operators need a better understanding of demand elasticities and strategies for managing load rebound at the conclusion of a control period.

Certain characteristics of end-use electric loads may cause them to be a more flexible and controllable resource than power plants. For example, demand responsive electric loads may be geographically isolated, thus providing advantages over power generation for controlling the electric grid by being available where most needed. Strategies can be developed to optimize DR programs for supply-constrained regions. Similarly, DR technologies can be developed to provide system operators with the

[2] ORNL. Demand Response Research Plan. Report to the California Energy Commission. October 2003.

ability to target specific geographic locations and select only the amount of load necessary to address individual shortage situations.

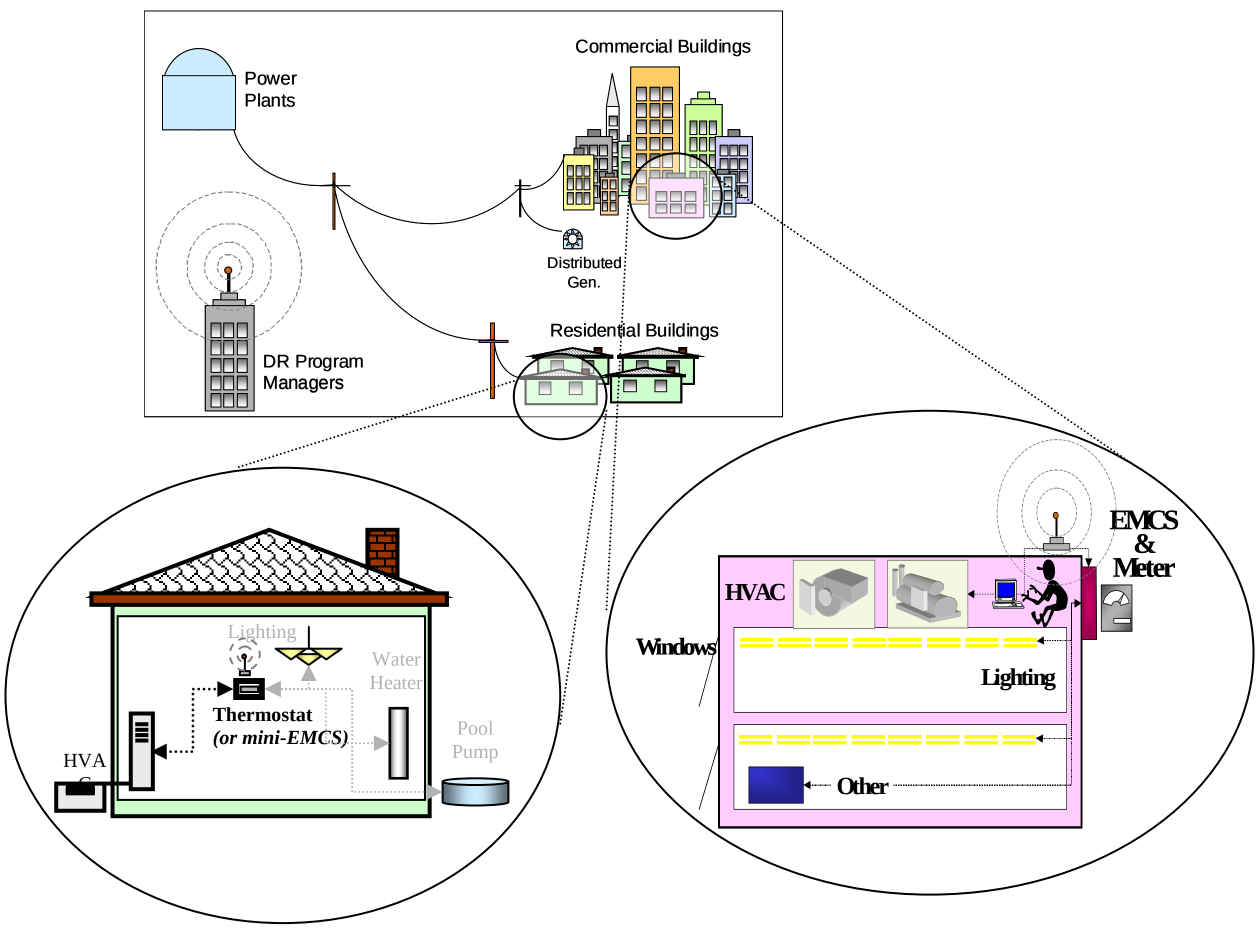
Electricity Markets and Pricing

Market-based DR programs and tariffs rely on electricity prices to modify load. Financial engineering models, such as option valuation models, are needed to evaluate the time and location value of demand response. Such models will also help define the size of DR resources under different electricity prices, market characteristics, and weather scenarios and forecasts, fostering improved methods for dispatch of DR resources.

System-Wide Information and Control

Electric loads should be responsive to the needs of the system in which they operate. The "system" can be thought of as the local geographic electric grid characteristics, or the broader statewide or western region electric grid. To accomplish this, demand-side systems need more intelligent and integrated control systems. These control systems should not only allow a collection of end-use systems to optimize their operation as a group, but also manage load across end-uses such as buildings and industrial facilities. **Figure 2** illustrates demand responsive end-use technology for residential and commercial buildings.

Figure 2. DR System Integration



Interaction of DR Infrastructure and Utility Communication Systems

The development and use of new DR infrastructure posses new problems and challenges for integration with electric utility-based infrastructure and communication systems. One example is how to integrate new interval metering systems with existing billing systems. Research is needed to improve understanding of issues such as methods, technologies, costs, benefits, and barriers to integrate new DR infrastructure systems with existing systems.

3.3 Customer and End-use Technology and Systems

Information Management for Demand Response

Successful DR in California will require end-use information systems, data monitoring and supervisory control systems that are designed and configured to execute various DR strategies. End-users include residential and commercial buildings, industrial facilities, and agricultural customers. Such systems are needed for all sectors, including buildings, industry, and agriculture. It will be important that these systems are not limited in function to DR, but also facilitate energy efficient and cost-effective end-use system operation. Ideally such technology will assist in maximizing the electric demand response, while minimizing any loss of service from changing operation of end use systems. *This research topic has been identified as a possible core research focus for the initial projects within the Center (see Appendix).*

To implement DR, it is expected that end-use customers, transmission and distribution companies, Independent System Operators, Utility Distribution Companies, and regulatory bodies may need specific electric consumption and DR information. The exchange of much of this information will likely be provided at the supervisory level of control and communications systems. This means that today's Energy Information Systems and Energy Management and Control Systems and related technology will need to change. This change will consist of either (1) evolving current systems to include the capabilities, or (2) replacing or augmenting supervisory level products that can perform these functions.

Energy Analysis Tools

Electricity customers can be quickly overwhelmed by the complexity of peak demand savings calculations. Most tools currently used within the building energy efficiency community emphasize energy savings analysis, not demand savings analysis. Peak hour modeling, scenario analysis, and cost-effectiveness analysis tools that account for uncertainty in building/system descriptions and dynamic rates are needed to help customers maximize cost savings, while minimizing risk. Accounting for uncertainty will greatly complicate these analyses. While this topic is listed here under Customer and End-use Technology and Systems, similar tools are needed for aggregators and utility planners, so information needs for such tools need to be evaluated with the key end-user in mind.

End-use Supervisory Controls and System Integration

In order to provide comfortable and energy efficient indoor environments that minimize peak demand, a building should continuously adapt its operation in response to climate and internal activities. This requires innovative, adaptable systems such as ventilation systems that are responsive to occupancy loads and outdoor air quality. Lighting systems whose output varies with daylight availability, occupancy, and task requirements are needed. Emerging electro-chromic windows manage solar load and glare to minimize summer peak cooling loads and maximize the use of daylight to replace overhead electric light. Significant research is needed to develop HVAC control strategies and systems that are demand responsive and can optimally control thermal loads, maintain indoor environmental health, and ensure productivity. Supervisory control strategies such as pre-cooling and temperature resets need to be evaluated for practical application in buildings. Functional test methods for DR strategies are needed to help ensure that new control strategies operate as intended, providing robust electric demand reduction with minimal loss of HVAC services. To accomplish this, future whole-building energy analysis tools and systems are needed to continuously re-optimize operations based on dynamically varying needs.

3.4 Consumer and Institutional Behavior

Behavior can be defined as "*the response of an individual, group, or species to its environment*". The DR environment will include dynamic tariffs, programs, technology, business rules, and other market characteristics of demand response. Demand response research should evaluate the ways in which people interact with the energy system, and how energy provides for the needs and desires of people and businesses. Human behavior will ultimately determine energy consumption patterns and demand, regardless of whether it is the result of a consumer preference for comfort, equipment, or service; the ability and motivation of a building operator to control load; or the action of a corporate CEO who has to decide whether to pay a premium for uninterruptible power.

Specific research topics to be considered will include the following. How does initial acceptance of DR programs and tariffs differ from sustained participation? Similarly, how do long-term levels of demand response differ from initial estimates from new participants in DR programs and tariffs? What quantitative and qualitative methodologies and techniques are needed to measure and evaluate 1) human factors associated with physical discomfort, and 2) business issues associated with interruption of normal building operations or industrial practices? Finally, what methods and program revenue allocation protocols will best overcome institutional arrangements (e.g. landlord/tenant lease language) that inhibit multi-tenant buildings from participation in DR programs and tariffs?

4 Next Steps

LBNL will work with the CEC to engage in a series of discussions with key stakeholders on the scope and feasibility of, and need and methods for Center research. A number of existing projects will be transferred into the Center. We propose to execute the following activities to launch the center:

1. Identify key stakeholders and potential Partners Planning Committee and Technical Advisory Group. Identify a Program Development and Outreach Manager and involve this Manager into the Center development.

2. Disseminate the Center plan to key stakeholders and potential Partners Planning Committee.

3. Conduct interviews and discussions with the potential Partners Planning Committee.

4. Finalize the Center Plan.

5. Disseminate final Center Plan to the proposed Partners Planning Committee.

6. Launch Center; hold initial Partners Planning Committee meetings.

7. Begin initial projects and multi-year planning process.

Appendix - Information Management for Demand Response

PROBLEM STATEMENT

Successful demand response in California will require building information, data monitoring and control systems that are designed and configured to execute various demand response initiatives. Further, it will be important that these building communication systems are not isolated in function to demand response, but also persistently facilitate energy efficient and cost-effective building operation.

To implement demand response, it is expected that certain information (e.g., DR validation) may ultimately be shared between building operators, T&D (transmission and distribution) companies, and regulatory oversight bodies. The exchange of the majority of this kind of information will probably be carried out at the supervisory levels of each organization's control and communications (C&C) infrastructure. This means that today's building Energy Information Systems (EIS), Energy Management and Control Systems (EMCS), and other related performance platforms will either evolve to include these capabilities or will be replaced by supervisory-level products that perform the required functions.

It has now become apparent that the variety of platforms being developed is progressing in a manner that may make it difficult to integrate and interoperate multiple subsystems. Understanding the inter-relationships and improving the interactions between the various types of "supervisory platforms" will allow various demand response and energy efficiency public interest goals to be achieved.

PROPOSED PROJECT

This project will focus on developing the science around software performance platforms at the ***supervisory*** level of building O&M (operations and maintenance), i.e., the highest level of the controls and monitoring hierarchy at which non-autonomic functions are decided.

The purpose of this project will be to initiate an evolutionary process of producing a reference design (a standard framework within which applications can be developed) for supervisory control and/or performance platforms that integrate public interest issues such as demand response and energy efficiency. In the current study with LBNL (Piette), the research team has recently published a report that compares and contrasts many of the "in-building" performance platform supervisory systems that exist today. The report classifies historical categories of performance platforms (e.g., EIS, EMCS, etc.) and presents their functional relationships to one another. In addition, the team is currently testing six of the most advanced of these platforms to see how they "automatically" respond to varying price signals. Depending on the results of these "demand response" tests, the team will then identify the generic supervisory characteristics that should be the preliminary basis of a performance platform reference design. This proposed project will continue field investigations, as necessary. This project will also meet with all relevant utility demand response project planners and implementers, building information, monitoring and control system manufacturers, standards bodies and trade organizations to cooperatively develop the supervisory platform reference design.

Ultimately, the goal of this research is to show the way toward the development of adaptable, multi-functional flexible supervisory strategies that can reside on affordable platforms for each building sector.

PROJECT SCOPE

The following lists of possible research activities are provided in an attempt to clarify the proposed scope of the project. These activities are examples only and should not be interpreted to encompass all research efforts either in or outside of the project scope.

In Scope

- Use of currently available EIS, EMCS, performance monitoring and diagnostics tools & strategies, as necessary, to demonstrate the functionality of the performance platform reference design

Out of Scope

- Direct product development that would meet the specifications of the reference design
- Performance monitoring and diagnostics tool & strategy development for building systems or components

BACKGROUND

The "controls and monitoring hierarchy" alluded to here is an abstract view (see **Figure A.1.**) of how different decision-making (non-autonomic) control responses and monitoring functions relate to one another. (An autonomic control response can occur without regard to supervisory instructions when pre-set conditions call for a non-negotiable action, e.g., when a smoke detector senses smoke, it can autonomically sound an alarm without first checking for instructions from its panel and supervisory controllers.)

The six-layer hierarchy in **Figure A.1.**. is defined as follows: The lowest layer (Device Layer) contains "unit controllers" that monitor and operate specific pieces of equipment; the next layer (Panel Layer) contains "panel controllers" that monitor and orchestrate the activities in domains such as all the equipment on a floor or all of the like-type equipment in a building. The two lowest layers are the domain of controls and communications (C&C) system components the measure, actuate, and communicate information. The third and fourth layers (User and Services Layers) do no physical monitoring and control, but gatherdata and turn it into useful information to be used in providing "services" (higher-level information). The fifth and sixth layers (Simulators and Executive Layer) are a "supervisory control" function that provides control strategies for the building.

The Information Management for Demand-Response Project and the Demand Response Research Center are primarily concerned with the four highest layers. These four, layers are also the domains of Control Strategies (as shown in the figure). Key issues such as the system integration (Executive Layer), comparison databases (Simulators Layer), demand-response (Services Layer), and machine-man interface (User Layer) are important in understanding and evaluating how demand-response control systems function.

The User Layer can be divided in two halves to indicate that some of the User Layer is concerned with supervisory control issues, and some is not. The DR Center and the Information Management for Demand-Response Project are concerned with the high level supervisory functions of the User Layer. The graphic Figure A.1 shows this distinction.At the supervisory decision-making level of the building controls hierarchy, economic, contractual, logistical (e.g., load changes), and competing (e.g., energy vs. comfort) building objectives are considered in the development of supervisory control strategies. Next, these control strategies are translated into specific physical actions. Control directives (in the form of new set-points) are sent automatically to embedded software and/or to a technician. Specific logic to perform physical actions involving monitoring, control logic, actuators, and communications already exist in the device and area controllers found in the panels, sensors, actuators, and manual switches. In the lowest levels of the hierarchy, there are

- Dumb equipment devices (DEDs) which cannot communicate and are limited to fixed sets of preprogrammed actions,
- Intelligent equipment devices (IEDs) which can communicate and can be given supervisory commands,
- Autonomic devices such as safety interlocks, alarm sensors, check valves, etc., and
- Manual switches and other technician-driven controls.

Over the last 20-plus years, since the advent of digital control technology in buildings, supervisory software began to replace certain manual operations. At first, the software only gathered data and displayed these data in familiar ways similar to the analog dials and charts they replaced. Then, the software was embedded in panels (or dedicated PCs) and directly connected to non-critical subsystems. At this point, the software provided automatic control of groups of sensors and actuators for well-defined control functions. Today, supervisory software resides on networked PCs and on remote servers connected to the building via the Internet. These systems provide a variety of monitoring, reporting and control functions. Eventually, components of the supervisory software will be widely distributed, residing even in unit controllers.

The latest and most-advanced versions of supervisory platforms are “Web or Internet enabled”. This means that it is possible for web sites to be created on secure off-site servers that address the needs of non-local users, i.e., users who are not on the building’s premises and directly attached to the building’s local area network (LAN). On-site building information users typically connect to a server located on an “intranet” protected from outside intrusion by a firewall. Non-local users, e.g., the local utility distribution company (UDC), the building's energy power supplier (EPS), the regional transmission organization (RTO), etc., get the information they need via the Internet.

The range of supervisory-type platforms that exists in buildings vary widely from systems that are "hardwired" and only monitor (and control) a few pieces of critical equipment (e.g., chillers) to web-enabled platforms that connect to the building's utility meters, zone-level HVAC equipment, other non-HVAC vendors' subsystems (e.g., security, fire, and life safety), and integrate with the building information technology (IT) infrastructure. These latter web-enabled systems come from several historically evolved perspectives. Some were initially built to manage HVAC systems (e.g., EMCS) that included more than one vendor's hardware; some were developed to only monitor energy usage in anticipation of deregulation (e.g., EIS); others provided power quality information for new digital age equipment requirements; and others came from software developments that focused on specific utility-driven demand-side management and other energy-related (e.g., efficiency) programs. There are also new supervisory platforms designed to aggregate and dispatch distributed generation (DG) assets. These DG supervisory platforms usually operate outside the building infrastructure but could eventually provide building supervisory control under certain developing micro-grid scenarios.

Figure A.1. Layered Building Control Systems